



United States  
Department of  
Agriculture

Animal and  
Plant Health  
Inspection  
Service

Plant  
Protection  
and  
Quarantine

# New Pest Response Guidelines

*Rhagoletis cerasi* (Linnaeus)

European Cherry Fruit Fly



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# Introduction

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New Pest Response Guidelines (NPRGs) are developed by Plant Protection and Quarantine (PPQ) in preparation for the plant health emergencies that occur when a new pest with the potential to seriously impact U.S. plant resources arrives in the U.S.

The purpose of an NPRG is to provide the basic information likely to be needed by the initial PPQ response team in the first 30 to 60 days following a detection of the pest in the U.S.

This guideline for European cherry fruit fly (ECFF), *R. cerasi* (Linnaeus), includes the following:

- ◆ Summary of relevant pest biology
- ◆ Guide to identification or screening for the pest in the field
- ◆ Preliminary method for conducting a delimiting survey
- ◆ Eradication and control options
- ◆ Summary of knowledge gaps

Note: This document is based on the best information available at the time of development; however, at the time of the emergency new scientific and technical information may be identified. In addition, each pest incursion has unique, site-specific characteristics that are impossible to predict. Therefore, this document should be considered a general guideline only. As the pest situation evolves and new information is gathered, the response implemented—including survey protocols—may need to be modified from the original recommendations.

Additional documentation in [Appendix D](#) includes specific information for grower host certification.

# Pest at a Glance

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## Pest Summary

*Rhagoletis cerasi* is univoltine and oligophagous (Boller and Prokopy, 1976) and is considered an important and highly destructive pest of *Prunus avium* (L.) L. (sweet cherries) in Europe (Daniel and Baker, 2013; Daniel and Grunder, 2012). Larvae develop inside the cherries, and without effective control methods, 100 percent of the fruit can be infested (Daniel and Baker, 2013; Fimiani, 1983).

## Justification

A photograph of a new fruit fly was taken in an urban park in Mississauga, Ontario, on 15 July 2015 (NAPPO, 2016). At the time, the fruit fly was tentatively identified as *R. cerasi*, and an initial detection survey was conducted by the Canadian Food Inspection Agency (CFIA). On 27 June 2016, the CFIA confirmed the detection of *R. cerasi* in association with *Lonicera* spp. (NAPPO, 2016).

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## Key Information

- ◆ *Rhagoletis cerasi* has a limited host range, infesting only *Prunus* spp. and *Lonicera* spp. (Daniel and Grunder, 2012)
- ◆ Without appropriate control measures, infestations can reach 100 percent, which can reduce marketable yields (Alford, 2007; Daniel and Grunder, 2012)
- ◆ Infested fruit damage tolerance levels in infested areas is typically set at 2 percent of infested fruit. Additionally, infested fruit cannot be sorted out, therefore the whole lot is rejected if tolerance levels are exceeded (Daniel and Grunder, 2012)

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## Previous PPQ Pest Reports and Assessments<sup>1</sup>

- ◆ **Objective Prioritization of Exotic Pests (OPEP)** – completed 29 February 2016
- ◆ **New Pest Advisory Group (NPAG)** – full report completed 15 April 2016
- ◆ **Cooperative Agricultural Pest Survey (CAPS)** – updated October 2016
- ◆ **Global Pest Disease Database (GPDD)** – last full review 9 March 2016
- ◆ **PestLens Articles**
  - European cherry fruit fly, *Rhagoletis cerasi* (Diptera: Tephritidae), detected in Canada (14 July 2016)

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<sup>1</sup> As of 28 November 2016



# Pest Overview

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## Pest Information

### Scientific Name

- ◆ *Rhagoletis cerasi* (Linnaeus)

### Taxonomic Position

- ◆ Animalia: Arthropoda: Insecta: Diptera: Tephritidae

### Synonym(s)

- ◆ *Rhagoletis fasciata* Rohdendorf, 1961

### Common Names

- ◆ **European cherry fruit fly**
- ◆ cherry fruit fly
- ◆ cherry maggot

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## Biology and Ecology

*Rhagoletis cerasi* is a univoltine (one generation per year) and oligophagous species with economic-pest status on sweet cherry. Its life cycle depends on the availability of *Prunus* and *Lonicera* spp. (honeysuckle) fruit (Daniel and Grunder, 2012). Two putative genetic host races, distinguished by observed oviposition preference for *P. avium* or *Lonicera xylosteum* L., have been described by Boller *et al.* (1998) in terms of phenological differences (the timing of adult emergence from pupae relative to the timing of the host fruit-development stage) and behavioral differences (plasticity of host choice by ovipositing females; sensitivity to the host-marking pheromone deposited on host fruit by females after oviposition). However, in looking for genetic differences between the two phenotypes, only one of six examined allozyme loci suggested genetically distinct

races (Schwarz *et al.*, 2003). Infection by one or more strains of *Wolbachia* may contribute to genetic differences among geographically dispersed populations (putative genetically distinct northern and southern races) via reproductive isolation through the mechanism of *Wolbachia*-induced cytoplasmic incompatibility (Arthofer *et al.*, 2009b; Riegler and Stauffer, 2002); although the potential contribution of other factors (geographic isolation; host distribution) has not been refuted (Augustinos *et al.*, 2014). For the objectives and audience of this NPRG, the difference in emergence time of adults from pupae that developed beneath cherry trees, relative to those that developed beneath honeysuckle bushes, may be the most relevant distinction for those charged with responding to detection of an introduction of *R. cerasi* in a newly-invaded landscape (see [Timing of Surveys](#), below).

This species overwinters as diapausing pupae in soil proximal to the host (cherry or honeysuckle) (Daniel and Grunder, 2012). Maximum emergence of adults occurs after approximately 180 days at temperatures below 5 °C during a pupal hibernation period of 9–10 months (Daniel and Grunder, 2012). However, Moraiti *et al.* (2014) showed that pupae collected from sites representing a wide range of host and climatic conditions accommodated varying temperature regimes through varying diapause duration. Fly emergence usually occurs from mid-May to mid-June in southern Germany, Switzerland and Austria (latitudes 46–48 °N) when temperatures are above 15 °C. The emergence of adults from pupae in soil beneath *Lonicera* spp. lags a few days behind that of adults that emerge from pupae proximal to cherries (Daniel and Grunder, 2012).

Based on variation in fly fitness, larval nutrition, host phenology and ambient temperatures, the period of adult emergence, flight, mating and oviposition can range from 7–11 weeks. Estimates of the life span of adults in the field range from 4–7 weeks (Daniel and Grunder, 2012).

Eggs are oviposited into host fruit (Daniel and Grunder, 2012). There are three instars between the egg and adult stages; larval development occurs in host fruit. Embryonic development after oviposition into host fruit takes 2–10 days, depending on temperature. The duration of larval development varies with temperature and host quality. Larval development concludes when pre-pupal larvae emerge from host fruit, drop to proximal soil and burrow to a depth of 2 to 5 cm beneath the surface to pupate (Daniel and Grunder, 2012).

*Rhagoletis cerasi* overwinters in the pupal stage in soil beneath perennial hosts (cherry and honeysuckle) (Daniel and Grunder, 2012). The duration and success of pupal development and adult emergence are influenced by host nutritional quality during the larval stage and soil temperature. Most adults emerge at the conclusion of one cycle of winter diapause; however, for varying percentages of

individuals, pupation continues through two or more winters, thus ensuring survival during years when cherry fruits are not produced (Daniel and Grunder, 2012). This multiyear overwintering strategy should be considered when quarantine regulations are enacted.

Models exist for predicting adult emergence based on soil temperature at 5 cm depth (Daniel, 2014). Adult emergence begins after 430 degree days above the pupal (soil) developmental threshold temperature of 5 °C (Daniel, 2014).

The preoviposition period lasts six to 13 days, during which maturation of gonads concludes while adults feed on bacterial colonies inhabiting the surface of host leaves and fruit, honeydew, extrafloral nectaries and bird feces (Daniel and Grunder, 2012).

Adults aggregate onto sunlit portions of the host when the temperature is above 15 °C to mate (Daniel and Grunder, 2012). Ambient conditions favorable to mating and oviposition most often occur on the southeast portion of the host. Fecundity ranges from 30–200 eggs per female; fertility ranges from 54–100 percent (Daniel and Grunder, 2012).

Males guard individual cherries and emit a species-specific pheromone (Daniel and Grunder, 2012). The relative importance of this pheromone and of host quality cues to the selection of an oviposition host is unclear. After forced copulation with a male guarding the host cherry, the female pierces the cherry with her ovipositor and oviposits a single egg in the fruit; she then marks the cherry with a host-marking pheromone to preserve the resource for the single egg. However, during years of heavy infestation, multiple larvae have been found in a single cherry (Daniel and Grunder, 2012).

Factors determining the time of oviposition initiation include the nutritional state of females, ambient temperature and degree of cherry fruit maturity (Daniel and Grunder, 2012). The time between mating and oviposition is unclear; it may be based on insolation and temperature. High levels of infestation are associated with prolonged periods of sunny weather and temperatures above 15 °C (Daniel and Grunder, 2012)

Oviposition occurs at midday on sunny days when temperatures are above 16 °C (Daniel and Grunder, 2012). The fruit fly prefers sweet cherries over *Prunus cerasus* L. (sour cherries), consistent with research demonstrating that subsequent larval development is more rapid and successful in pulp of lower acidity and higher sugar content. In sweet cherries, the preferred oviposition host is a fruit with pulp thickness of 5 mm or more, a hardened pit and a color stage transitioning from green to yellow (Daniel and Grunder, 2012). Within orchards, ovipositing females will move to adjacent *Lonicera* spp. berries when cherries

have already ripened and been harvested (Daniel, 2014). Adults that developed as larvae in *Lonicera* spp. berries have demonstrated a preference for *Lonicera* spp. berries as oviposition hosts (Daniel and Grunder, 2012).

## Hosts

**Table 3-1** List of reported plant hosts of *R. cerasi*

Scientific name	Common name	References
<i>Lonicera alpigena</i> L.	alpine honeysuckle	Boller <i>et al.</i> (1998) GRIN (2016)
<i>Lonicera bella</i> Zabel	Bell's honeysuckle	
<i>Lonicera morrowii</i> A. Gray	Morrow's honeysuckle	Bullas-Appleton (2016) GRIN (2016)
<i>Lonicera</i> spp.	wild honeysuckle	White and Elson-Harris (1994)
<i>Lonicera tatarica</i> L.	Tartarian honeysuckle	Boller <i>et al.</i> (1998) GRIN (2016)
<i>Lonicera xylosteum</i> L.	European fly honeysuckle	Boller and Prokopy (1976) Boller <i>et al.</i> (1998) GRIN (2016)
<i>Prunus avium</i> (L.) L.	sweet cherry	Boller <i>et al.</i> (1998) GRIN (2016)
<i>Prunus cerasus</i> L.	sour or tart cherry	Boller and Bush (1974) GRIN (2016)
<i>Prunus mahaleb</i> L.	mahaleb cherry	Daniel and Grunder (2012) GRIN (2016) Leski (1963)
<i>Prunus padus</i> L. <sup>1</sup>	European bird cherry	GRIN (2016) Kotte (1958)
<i>Prunus serotina</i> Ehrh.	black cherry	Daniel and Grunder (2012) GRIN (2016)
<i>Prunus</i> spp.	wild cherry	White and Elson-Harris (1994)
<i>Symphoricarpos albus</i> (L.) S. F. Blake (= <i>Symphoricarpos racemosus</i> Michx.) <sup>1</sup>	snowberry	GRIN (2016) Kotte (1958)

<sup>1</sup> Can develop in the fruits, but to a limited extent

<sup>2</sup> Adult associated host

## Dispersal

### Natural Dispersal

*Rhagoletis cerasi* rarely move far from their host plants, and disperse only when deprived of suitable fruits for oviposition due to early harvest or frost (Boller and Prokopy, 1976; Daniel and Grunder, 2012). It is at this point that females, followed by males, move from tree to tree until they find a suitable host.

Laboratory studies have shown that *R. cerasi* is capable of flying more than 1 km in 24 hours (as cited in Daniel and Baker (2013)), although studies conducted under field conditions indicated that their maximum flight distance is between 100 and 500 m, and in unique cases, as far as 3 km when no landing platforms are available (as cited in Daniel and Grunder (2012)). Within orchards, 95 percent of adults move to adjacent, late-ripening trees, and from there to *Lonicera* spp. bushes (Daniel and Grunder, 2012; Leski, 1963). Wind may also play a role in dispersal of adults (Daniel and Baker, 2013; Thiem, 1934).

## Human-Assisted Spread

Movement of infested fruit is most likely the primary way *R. cerasi* is spread with human assistance (Daniel, 2017). It is nearly impossible to sort out infested cherries, and when marketed, the consumer will eventually notice the larvae. Thereafter, if put on a compost pile, larvae that survive and form pupae might be able to overwinter (Daniel, 2017).

The movement of plants for planting could possibly involve soil infested with *R. cerasi* pupae (Landry and Mordecai, 2016). Larvae develop inside the fruit and drop to the soil under the tree canopy to pupate and overwinter (Boller, 1966).

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## Potential Pathways of Introduction

The introduction of *R. cerasi* into the U.S. would most likely be through the importation of infested cherry fruit. Between 1988 and 2016, *R. cerasi* immatures have been intercepted 114 times in fruit in baggage at U.S. ports of entry (PestID, 2017). Although there is no indication of an open commercial pathway of commercial cherry fruit imported from regions where *R. cerasi* is known to be established (Landry and Mordecai, 2016), there is evidence of other Tephritidae entering the country, primarily in passenger baggage (Bigsby *et al.*, 2016; Liebhold *et al.*, 2006).

Research conducted by Szyniszewska *et al.* (2016) indicated that *Ceratitis capitata* (Wiedemann) (Mediterranean fruit fly) gains entry into Florida and California predominantly in infested fruit that is carried by airline passengers. Further analysis on fruit fly interceptions at U.S. ports-of-entry from 2005 through 2014 indicated that Tephritidae were intercepted on items for consumption (fruit) 96.8 percent of the time and that 96.2 percent of all pest interceptions were in international passenger baggage (Bigsby *et al.*, 2016).

## Geographic Distribution

### Ecological Range

**Table 3-2** Ecological range of *R. cerasi*

Region	Country	References
Asia		
	Armenia	Foote (1984)
	Azerbaijan	Foote (1984)
	Belarus	Foote (1984)
	Georgia	Foote (1984)
	Iran	Derakhshan (2009) Namin and Rasouljan (2009)
	Kazakhstan	Foote (1984)
	Kyrgyzstan	Foote (1984)
	Tajikistan	Foote (1984)
	Turkmenistan	Foote (1984)
	Uzbekistan	Foote (1984)
Europe		
	Austria	Boller <i>et al.</i> (1976)
	Bosnia and Herzegovina	Nježić <i>et al.</i> (2016) Riegler and Stauffer (2002)
	Bulgaria	Boller and Bush (1974) Boller <i>et al.</i> (1976)
	Crete	Moraiti <i>et al.</i> (2012)
	Croatia	Bjeliš (2008) Riegler and Stauffer (2002)
	Czech Republic	Falta <i>et al.</i> (2005) Riegler and Stauffer (2002)
	Denmark	Ravn and Rasmussen (1994)
	Estonia	Foote (1984) Kütük and Özaslan (2006)
	France	Boller <i>et al.</i> (1976) Moraiti <i>et al.</i> (2014)
	Germany	Boller <i>et al.</i> (1976) Moraiti <i>et al.</i> (2014)
	Greece	Boller <i>et al.</i> (1976) Moraiti <i>et al.</i> (2014)
	Hungary	Boller and Bush (1974) Boller <i>et al.</i> (1976)
	Italy	Caruso and Boselli (2008) Fimiani (1984)
	Latvia	Stalažs (2014)
	Lithuania	Lutovinovas (2014)
	Moldova	Kiskin <i>et al.</i> (1981)

	Netherlands	Boller and Bush (1974) Boller <i>et al.</i> (1976)
	Norway	Jaastad (1994)
	Poland	Olszak and Maciesiak (2004)
	Portugal	Arthofer <i>et al.</i> (2009a)
	Republic of Macedonia	Bandzo <i>et al.</i> (2012)
	Romania	Boller <i>et al.</i> (1976)
	Russia	Augustinos <i>et al.</i> (2014)
	Sardinia	Proto (1979)
	Serbia	Stamenkovic <i>et al.</i> (2012)
	Sicily	Piccionello and Caleca (2012)
	Slovakia	Boller and Bush (1974) Boller <i>et al.</i> (1976)
	Slovenia	Riegler and Stauffer (2002)
	Spain	Boller <i>et al.</i> (1976) Riegler and Stauffer (2002)
	Sweden	White and Elson-Harris (1994)
	Switzerland	Jaastad (1998)
	Turkey	Kepeneci <i>et al.</i> (2015) Kütük and Özaslan (2006)
	Ukraine	Riegler and Stauffer (2002)
	Yugoslavia	Boller and Bush (1974) Boller <i>et al.</i> (1976)
North America		
	Canada (Ontario)	NAPPO (2016)

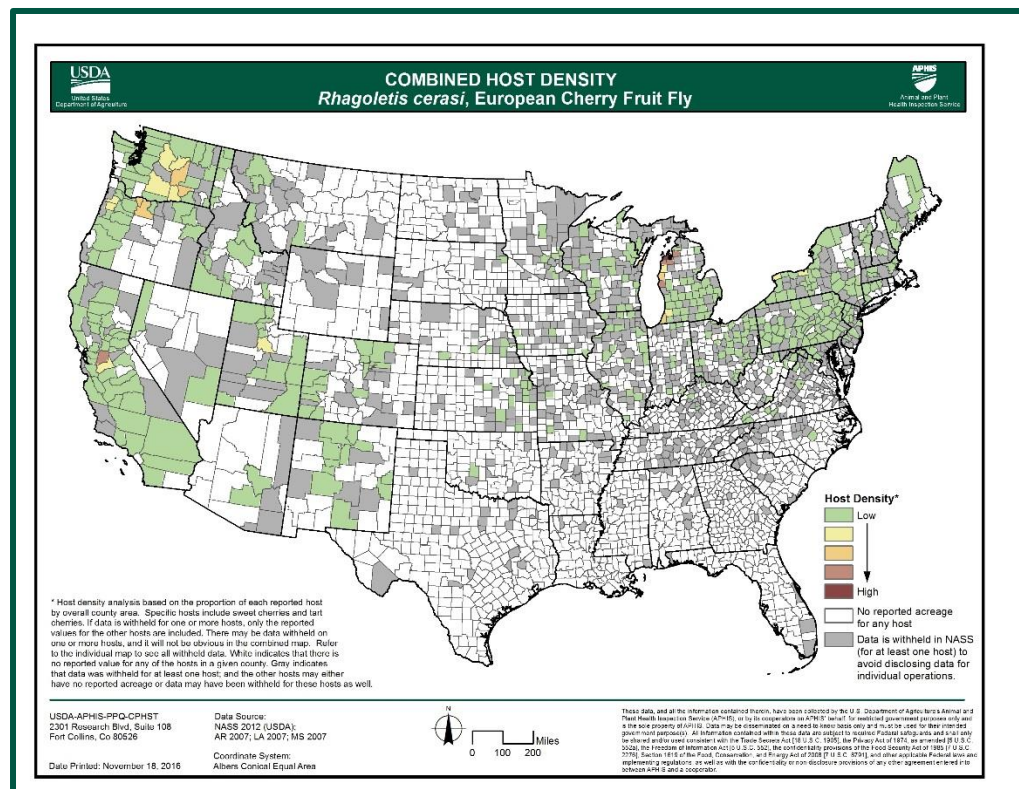
## Potential Distribution in the United States

Boller and Remund (1983) determined that emergence of *R. cerasi* requires 430 degree-days above a base developmental temperature of 5 °C. Various other studies conducted also determined that in order for the maximum emergence of *R. cerasi* adults to occur, temperatures had to be below 5 °C for approximately 180 days (Daniel and Grunder, 2012; Leski, 1963; Thiem, 1934; Vallo *et al.*, 1976).

Moraiti *et al.* (2014) recently determined that diapause termination could successfully occur with winter temperatures at 8 °C and that diapause intensity and temperature requirements can vary depending on the geographic origin of the population.

Tart cherry distribution in the U.S. is mainly in Michigan, while sweet cherries are produced in the western and northeastern parts of the U.S. with the highest host densities in California, Michigan, Oregon and Washington (Fig. 3-1) (USDA–APHIS–PPQ–S&T Fort Collins Lab, 2016; USDA–NASS, 2016). These states represent plant hardiness zones 6–11 (USDA, 2015).





**Figure 3-1** Density map of combined hosts (sweet and sour cherries) depicting possible host areas for *R. cerasi* to establish in the continental United States (USDA-APHIS-PPQ-S&T Fort Collins Lab, 2016)



# Pest Identification and Damage

## Species Description/Morphology

### Adults

Adult flies feature a prominent yellow scutellum, shiny black thorax and wings characterized by clear translucent regions variegated with near-opaque gray or black regions. Females measure approximately 5 mm ([Fig. 4-1](#)); males, 4 mm ([Fig. 4-2](#)) (Daniel and Grunder, 2012).



**Figure 4-1** *Rhagoletis cerasi* female (image credit Claudia Daniel, Research Institute of Organic Agriculture FiBL)



**Figure 4-2** *Rhagoletis cerasi* male (image credit Claudia Daniel, Research Institute of Organic Agriculture FiBL)



**Figure 4-3** *Rhagoletis cerasi* male and female mating (image credit Claudia Daniel, Research Institute of Organic Agriculture FiBL)

## Eggs

Eggs are white, oblong and approximately  $0.25 \times 0.75$  mm. They are deposited into host fruit immediately beneath the fruit skin (Daniel and Grunder, 2012; Mouzaki and Margaritis, 1991).

## Larvae

Larval development occurs within the host fruit, where larvae feed on fruit pulp; neonates tunnel toward the cherry pit to avoid predators and parasitoids. There are three instars; mature third instar larvae are translucent white and measure approximately 6 mm long (Fig. 4-4) (Daniel and Grunder, 2012).



**Figure 4-4** Newly hatched *R. cerasi* larvae with an empty eggshell and an egg shortly to hatch (image credit Claudia Daniel, Research Institute of Organic Agriculture FiBL)

## Pupae

Prepupal third instars form exit holes in the fruit skin as they emerge to drop to the soil beneath the host, where they quickly burrow and pupate (Fig. 4-5). The depth of pupation varies with soil texture, from 2 cm in clay soils to 5 cm in sandy soils. The puparium is cylindrical, approximately 2 × 4 mm and straw yellow. Pupae are the overwintering stage and remain in the soil for 9–10 months, as studied in Germany, Switzerland and Austria (Daniel and Grunder, 2012).



**Figure 4-5** *Rhagoletis cerasi* pupae (image credit Claudia Daniel, Research Institute of Organic Agriculture FiBL)

## Signs and Symptoms

Larval maturation within cherry fruit is associated with sunken brown lesions (Fig. 4-6) (Noma *et al.*, 2010). Exit holes remain after the pre-pupal larvae exit the cherry fruit to pupate in soil beneath the host (Fig. 4-7) (Daniel and Grunder, 2012).



**Figure 4-6** Damage inside cherry from *R. cerasi* pupae (image credit Claudia Daniel, Research Institute of Organic Agriculture FiBL)





**Figure 4-7** Exit holes from *R. cerasi* (image credit Claudia Daniel, Research Institute of Organic Agriculture FiBL)

## Similar Species

There are three other *Rhagoletis* spp. that also infest cherries in the United States.

- ◆ *Rhagoletis cingulata* (Loew) (Eastern cherry fruit fly) is found in the eastern United States, southeastern Canada and Mexico (Bush, 1966; Rull *et al.*, 2011; Yee *et al.*, 2014). Since 1983, this species has also been detected in various countries in Europe (Bjeliš, 2008; Egartner *et al.*, 2010; Lampe *et al.*, 2005)



**Figure 4-8** *Rhagoletis cingulata* adult (image credit Tom Murray)

- ◆ *Rhagoletis indifferens* Curran (Western cherry fruit fly) is found in the northwestern United States and in British Columbia, Canada (Bush, 1966; Foote, 1984; Yee *et al.*, 2014)



**Figure 4-9** *Rhagoletis indifferens* adult (image credit E. Beers, Orchard Pest Management Online)

- ◆ *Rhagoletis fausta* (Osten Sacken) (black cherry fruit fly) is found in the eastern and western United States and in eastern Canada (Bush, 1966; Foote, 1984; Yee *et al.*, 2014)



**Figure 4-10** *Rhagoletis fausta* adult (image credit Tom Murray)

There is one other species, *R. berberidis* Jermy, that is similar to *R. cerasi*, but that is not present in the United States. Keys to differentiating each of these fruit

flies to species level have been described by Bush (1966), Merz (1994), White (1988) and White and Elson-Harris (1994).

# Delimitation Survey

When one or more European cherry fruit flies are collected in an area, implement a delimiting survey immediately to determine the population distribution. The standard fruit fly delimitation design that has been approved for all other exotic tephritids is recommended. Collection of adults can be accomplished with trap and lure combinations. An alternative method that can also be used is sweep netting (Jackson and Moylett, 2016).

During ECFE outbreaks, the USDA and relevant State Departments of Agriculture will operate under Unified Command and each agency will designate an incident commander to be responsible for the overall project and administrative functions.

If circumstances warrant, the Unified Command may request the assistance of APHIS–PPQ’s Incident Management Team. The project will use the Incident Command System in handling the project activities.

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## Technical Support Representatives

- ◆ Technical Working Group (TWG): Consists of scientists and program managers recommended by TDA/USDA for their expertise on the pest. The TWG advises Unified Command or APHIS/TDA management on current research and technology as well as on the biological soundness of treatments and the detection program. The TWG meets as needed to develop recommendations and submit them to Project Management, the Commissioner and industry
- ◆ Legal Counsel: State or federal attorneys who advise on the legal basis for enforcement decisions and the validity of claims, and who defend the program in court
- ◆ Medical Coordinator: A pesticide toxicologist who advises on public health implications of the treatment program
- ◆ Animal Health Coordinator: A veterinarian who advises on potential animal health risks of the treatment program and liaises with veterinary groups



- ◆ Industry Representatives: Technical representatives who advise on methods of treatment application and represent grower issues

## Delimitation Area

The total delimitation area may depend on information from trace-back and trace-forward investigations; pest identification; the nearby host distribution, Pest Identification and including the extent of natural and artificial dispersal; agency resources and logistics. The delimiting survey boundaries can be as specific as production sites or as broad as political or geographical boundaries.

Along with other factors, the delimited area depends on the flight capacity of the exotic pest. The delimitation area may also be influenced by other specifics that are only known at the time of introduction. For instance, the location of introduction, occurrence of high-risk pathways, density and distribution of hosts near the initial detection area, wind direction and available surveillance resources at the time of introduction all may influence the delimitation area.

The range of dispersal of *R. cerasi* is determined by the availability of host fruit; thus, the delimited area can be determined by host distribution.

## Traps and Placement

The [CAPS approved method](#) is a protein-baited yellow sticky card with a lure of ammonium acetate in a polycon dispenser (Molet and Moylett, 2016). Place traps around the perimeter of the orchard and in the middle section of the tree canopy on the outside edge of the tree with the yellow surface of the trap facing outward (Molet and Moylett, 2016). Traps may also be placed in honeysuckle. If the main stem is large enough, hang the trap; if not, use a wooden or metal stake placed in close proximity to the host, making sure the trap is level with the crown of the plant (Molet and Moylett, 2016).

Following the confirmation of a detected specimen as ECFF, increase trap densities in the core square-mile area within 24-48 hours. Optimally, place traps over an 81-square mile area in a 100-50-25-20-10 array ([Fig. 5-1](#)) (USDA–APHIS–PPQ, 2003). This includes a core mile area surrounded by four concentric buffer square miles for a total of approximately 81 square miles depending on the factors mentioned above. Increase trap densities in the remainder of the trapping area from the core outward, if possible, within 72 hours of the find ([Table 5-1](#)) (USDA–APHIS–PPQ, 2003). Reduce overall trap numbers if there are areas that do not support hosts. For example, if any square mile of the area contains only 25 percent hosts, then the total numbers recommended in that square mile would be

reduced by approximately 75 percent.

4	4	4	4	4	4	4	4	4
4	3	3	3	3	3	3	3	4
4	3	2	2	2	2	2	3	4
4	3	2	1	1	1	2	3	4
4	3	2	1	C	1	2	3	4
4	3	2	1	1	1	2	3	4
4	3	2	2	2	2	2	3	4
4	3	3	3	3	3	3	3	4
4	4	4	4	4	4	4	4	4

**Figure 5-1** Array pattern for placing the traps in the field: (C) core area; (1) 8 square miles around the core area; (2) next 16 square miles outward; (3) next 24 square miles and (4) outermost 32 square miles (USDA–APHIS–PPQ, 2003)

**Table 5-1** Trap distribution, density and possible total number of traps in the array areas. The core area has the densest level of traps, and subsequent trapping levels are reduced, moving out toward the outer buffer (USDA–APHIS–PPQ, 2003)

Area	Buffer	Total mi <sup>2</sup>	Traps/ mi <sup>2</sup>	Total traps
C	core area	1	100	100
1	1 mi <sup>2</sup>	8	50	400
2	2 mi <sup>2</sup>	16	25	400
3	3 mi <sup>2</sup>	24	20	480
4	4 mi <sup>2</sup>	32	10	320
	total mi <sup>2</sup>	81	(varies)	1700

## Trap Servicing

During the first week, service traps in the core mile daily. If you find a second fly during this first week of intensive trapping, service traps in the core area twice weekly and place increased emphasis on servicing traps in the buffer areas in an effort to better delimit the infestation (USDA–APHIS–PPQ, 2003). Traps in the eight square miles around the core need to be serviced every two days. Check all other traps at least once within the first week. Service all traps weekly for three life cycles of the fly beyond the last fly detected. Relocate traps to available preferred hosts as practical (USDA–APHIS–PPQ, 2003).

Once the ammonium acetate dispenser has been expelled, discard the polycon and replace it with a new pre-loaded polycon (Molet and Moylett, 2016). Polycon

dispensers are refillable, but for ease of use, pre-loaded, single-use devices are to be used. Therefore, do not attempt to re-load the dispensers.

## Other Survey Techniques for Delimitation

Overwintering pupae are found in soil proximal to the host, at a depth of 2–5 cm, varying with soil texture from clayey to sandy (Daniel and Grunder, 2012). A method for sampling soil and extracting pupae has been described for the [Western cherry fruit fly](#) (AliNiazee, 1974).

### Sampling of Soil for Pupae

The soil depth at which the 2 × 4 mm pupae have been reported to pupate has ranged from 2 cm in clay soils to 5 cm in sandy soils (Daniel and Grunder, 2012).

AliNiazee (1974) described a wet-sieving method for surveying cherry orchard soils in western Oregon (Albany) for pupae of the western cherry fruit fly. Most pupae were found within 10 cm of the soil surface; however, up to 12.5 percent of pupae in a sampled area were found at a depth of 15.24 cm.

- ◆ Collect soil beneath host using a sample size of 30.5 cm × 30.5 cm diameter × 2.5 cm depth., down to 15.24 cm in depth
- ◆ Transfer sample to a 10-mm mesh sieve
- ◆ Shake sample on sieve under a stream of water to separate pupae and soil from vegetation and roots. Collect pass-through
- ◆ Transfer pass-through sample to a 5-mm mesh sieve
- ◆ Shake sample under a stream of water. Collect pass-through
- ◆ Transfer pass-through sample to a 0.84-mm mesh sieve
- ◆ Shake sample under a stream of water; 0.84-mm mesh sieve will retain pupae
- ◆ Transfer retained sample from 0.84-mm mesh sieve to a flat white porcelain pan
- ◆ Add tap water to float *Rhagoletis* pupae for collection

### Visual Inspection for Larvae during Delimiting Survey

In addition to flight-interception trapping of adults, larval surveys are conducted in host fruit (Daniel and Grunder, 2012). Signs and symptoms of *R. cerasi* larval activity in cherries include presence of ovipositing adults on fruit, darkening of fruit, soft spots on fruit, exit holes on fruit made by mature (pre-pupal) larvae, shriveled or wilted fruit and rotten fruit (USDA–APHIS–PPQ–CPHST, 2016). Additionally, fruits may be sliced to actively look for larvae. A method of

surveying cherry and honeysuckle fruit for larvae is described by Daniel and Grunder (2012):

- ◆ Collect 100 ripe cherries or *Lonicera* spp. berries
- ◆ Crush fruits to a degree sufficient to dislodge and separate the pits
- ◆ Add the de-pitted fruits to a 1,000-ml aqueous solution containing 350 g salt
- ◆ After 10 minutes of immersion, count floating larvae

## Timing of Surveys

*Rhagoletis cerasi* is univoltine and overwinters as pupae in soil proximal to the host. Pupal diapause concludes after 180 days below 5 °C; adult emergence occurs after 430 day-degrees above that temperature (Daniel and Grunder, 2012).

The period of adult emergence, flight, mating and oviposition can range from 7–11 weeks, coinciding with temperatures above 15 °C (Daniel and Grunder, 2012). Adult emergence begins after 430 degree days above the pupal (soil) developmental threshold temperature of 5 °C (Daniel, 2014). Models exist for predicting adult emergence based on soil temperature at 5 cm depth (Daniel, 2014). The emergence of adults from pupae in soil beneath *Lonicera* spp. lags a few days behind that of adults that emerge from pupae proximal to cherries (Daniel and Grunder, 2012).

After adult emergence and feeding on the host and in the vicinity of the host to promote sexual maturity, mating and oviposition occurs where the host fruit is exposed to sunlight. Adults prefer sweet cherries over sour cherries; in sweet cherries, the preferred oviposition host is a fruit with pulp thickness of 5 mm or more, a hardened pit and a color stage transitioning from green to yellow (Daniel and Grunder, 2012). Larvae develop in cherries until they have matured and leave the fruit to pupate in adjacent soil or until fruit are harvested or destroyed by disease organisms or weather events (Daniel and Grunder, 2012).

Guidance for CAPS suggests surveying for *R. cerasi* adults in the U.S. from May through July, when weather conditions are hot and dry (USDA–APHIS–PPQ–CPHST, 2016). Survey of cherry fruit for larvae can begin soon after oviposition begins in mid-June and when host fruit starts to become available (USDA–APHIS–PPQ–CPHST, 2016).

# Eradication and Control Procedures

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This chapter presents known control options available for this pest and summarizes how widely used they are in the United States.

This information can be used by PPQ decision-makers after a detection to assess the suitability of potential actions to eradicate, contain or suppress *R. cerasi*. The efficacy and feasibility of each control option will depend on the pest situation at the time of detection. Factors such as where the pest is detected (*i.e.*, natural or urban environment, agricultural crops, greenhouses), how widespread the pest is, the climatic region, the time of year, the phenology of the host and what current practices are already in place contribute to determining whether a particular control option is appropriate. With respect to detection of an introduction of *Rhagoletis cerasi*, in the absence of recurring introductions, the prospect of eradicating a small, geographically isolated population of this oligophagous, univoltine species is favored by its susceptibility to three classes of chemical insecticides (see below).

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## Regulatory Procedures

- ◆ Hold Notices: After an infestation is known to exist, operations personnel will issue hold orders on all properties known to be infested with ECFF
  - ◆ Emergency Quarantine: An emergency quarantine shall be adopted if any of the infestation criteria listed under Eradication Activities is fulfilled
- 

## Criteria for Declaration of an Infestation and Initiation of Eradication Activities

- ◆ Two adults or more within three miles of each other and within a time period equal to one life cycle of the fly,
- ◆ One mated female (known or suspected to have been mated to a wild male)\* **or**
- ◆ Larvae or pupae

## Environmental Assessment and Public Notifications Regarding Eradication Treatments

At the time of an eradication treatment, a site specific Environmental Assessment will be completed and a Finding of No Significant Impact (FONSI) signed, and the public will be notified regarding the findings.

The purpose of notification is to comply with state/federal law and present accurate information in an understandable and non-threatening format to concerned groups. Local and state elected representatives of the residents in the treatment area will be notified and apprised of major developments before and during treatment. During ground treatment activities, any resident whose property will be treated with foliar sprays following the discovery of infested fruit on or near their property will be notified in writing prior to treatment. Treatment notices include the name of the pest to be eradicated, the material to be used and a phone number to call in case of additional questions on project operations. Following treatment, a completion notice is left detailing any precautions the homeowner should take, including harvest intervals on treated fruit. Treatment without prior notification may be necessary on a small number of properties if active larvae are detected. However, reasonable efforts will be made to contact the homeowner.

In the event of aerial treatment operations, notification will be made either by hand delivery or first class mail at least 72 hours before the first pesticide application begins, or in a declared emergency situation, at least 24 hours before treatment (USDA–APHIS, 2015). The information contained in the notice will include that noted above plus the aerial treatment boundaries and the number of a toll-free hotline to answer health related questions.

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## Eradication Methods and Procedures

### Control Tactics

Ground control is comprised of three elements: **foliar bait spray treatments** of host and/or non-host plants with hand or mechanical ground spray equipment, **soil drenching** hosts around larval or mated female detections and **removal of all fruit** (fruit removal). Foliar bait spray treatments target the adult life stage of the fruit fly. Soil drenching under the drip-line of a host plant targets the larval or pupae stage in the soil. Fruit removal is conducted in order to break the life cycle by eliminating any potential hosts for egg oviposition and larval development.

The following outline has been developed to provide direction through the initial stages of a ground control program:

- ◆ Control triggers are met, fly identification is confirmed and a treatment area is defined based on fly distribution and the current action plan
- ◆ State Agricultural authorities and regulations are required and used for official plant pest eradication and pesticide treatments for intrastate quarantines. Federal and state program officials must work together on control and eradication of plant pests
- ◆ Compliance with the Endangered Species Act and NEPA: A site specific Environmental Assessment will be required and prepared by the APHIS Environmental Risk Assessment Staff (ERAS). Also, sensitive environmental sites to be excluded from treatment are identified in cooperation with the Department of Environmental Protection, the U.S. Fish and Wildlife Service and local government agencies
  - Environmental and Biological Assessments conducted prior to treatment
- ◆ The Public Information Officer (PIO) must issue a public notification via the news media at least 24 hours in advance of treatment. This notification should include treatment area boundaries, common roadways and landmarks for reference, anticipated dates of treatment, information about the pesticide used and the program help-line telephone number
- ◆ Equipment and personnel are mobilized. All control equipment is brought to a suitable location. Control personnel are contacted for immediate deployment: strike teams consisting of three to four 2-person units are assigned to sections of the treatment area, depending on equipment used. A strike team leader and teams commence control activities as soon as logistically possible.

## Treatment Notification

The following procedures pertain to foliar bait sprays and soil drench applications by ground-based treatment crews:

- ◆ Notify the property owner **24 hours** before treatment
  - Leave a Pre-Treatment Notification Form at the residence on the front door or in another visible place (do not leave the form in the property's USPS mailbox)
  - If contact is made and permission is granted, begin treatment
- ◆ When beginning treatment, attempt to make contact with the resident/homeowner
  - If contact is made and permission is granted, begin treatment
  - If no contact is made, begin treatment and leave a Post-Treatment

### Notification Form

- If the property owner refuses, then treatment is not conducted on the property

**IMPORTANT:** EVERY PROPERTY THAT IS NOT TREATED, FOR WHATEVER REASON, MUST BE RECORDED FOR FUTURE REFERENCE.

## Control Staging Area

A location should be selected that has the following characteristics:

- ◆ Close to the treatment area
- ◆ Secure for vehicles, chemicals, and equipment
- ◆ Equipped with a water source
- ◆ Equipped with a suitable office space and electricity
- ◆ Permeable area for mixing (if practical)
- ◆ Inconspicuous (out of sight of the public and press)
- ◆ Preferably away from the Incident Command Post (ICP)

## Foliar Bait Spray Treatments

Foliar bait spray treatment refers to the use of ground-control equipment, such as pump-up hand held sprayers, backpack sprayers, vehicle-mounted tank sprayers, *etc.*, to apply bait spray directly to the **underside** of foliage on hosts and non-hosts. Fruit flies are attracted to the protein hydrolysate and ingest the material, thereby receiving a lethal dose of the pesticide.

- ◆ Personnel numbers are dependent on the size of the area to be treated and the density of hosts and properties in that area
  - A two-person team can treat approximately 40 to 50 properties per day, based on host and property density
- ◆ Use the following formula to estimate the resources needed in urban or residential areas:
  - Assumptions: high density area = 2500 properties/mi<sup>2</sup>
  - Two-person team can treat 50 properties/day **or** 350 properties/7-day week
  - No. of sq. mi. to treat  $\times$  2500 = X;  $X/350$  = no. of control units needed for weekly application
  - Note: this calculation is for the number of two-person teams and does not include strike team leaders or other support personnel.
- ◆ Training and communication within the Control Branch are extremely important due to the close scrutiny the field personnel might encounter from the media and public. Inquiries from the media should always be



referred to the PIO

- ◆ A list of trained personnel for the Control Branch and support should be maintained and updated as necessary
- ◆ All personnel should be familiar with the Incident Command System (ICS) and have at least taken ICS-100 and ICS-200

Equipment for use in urban areas includes the following:

- ◆ Two-gallon pump-up sprayers have been the most efficient. Plastic sprayers are lightweight and economical. In order to minimize clogging, the sprayers and nozzles should be rinsed out at the end of each day
- ◆ Truck mounted sprayers: conduct calculations to determine the amount of material that can be applied using the minimum settings of the spray nozzle. A 100–200-ft hose can be used as long as you have sufficient pressure
- ◆ A supply truck should be stationed close to the treatment area in order to refill the sprayers with bait spray as needed throughout the day

## Chemicals

There are only two approved bait-insecticides for fruit fly eradication programs: **GF-120 Naturalyte®** (Spinosad, Dow AgroSciences LLC, Indianapolis, IN), an organically certified mixture of spinosad and fruit fly bait, and **malathion<sup>2</sup>** (various manufacturers) **plus Nu-Lure® Insect Bait** (Miller Chemical and Fertilizer Corp., Hanover, PA).

## Instructions for applying foliar bait sprays

GF-120 Naturalyte® (GF-120 NF) and malathion/Nu-Lure® bait-sprays must be applied as a low volume application, either as a hand-wand spot-spray or with ultra-low volume application equipment.

Hand-wand spray equipment for the bait-spray applications includes 2 to 4-gallon backpack sprayers and 1 to 5-gallon (pump-up) sprayers. Larger capacity spray equipment (ultra-low volume) may be used that can be adjusted or retooled to apply large droplet sizes (4-6 mm).

*Application Procedures:* Proper application techniques ensure 1) coverage of the target plants and 2) that an accurate dosage is applied for optimal fly control

<sup>2</sup> Not all crops or this defined application regime are listed on malathion labels. If your crop is not listed on the malathion label, malathion is illegal to use on your crop. Therefore, the GF-120 NF might be the only treatment option unless a Special Local Needs label can be obtained under the authority of §24(c) of FIFRA for the use of a federally registered malathion product to meet special local needs of the program.

- ◆ Spot treatments should be made by applying the bait spray to the underside of the canopy in order to reduce direct exposure to sun and rain
- ◆ A large spray droplet size of 4 to 6 mm is recommended to optimize the length of bait attractiveness
- ◆ Begin applications as soon as monitoring indicates flies are present. Applications should be made every 7 to 14 days. Always refer to the label for timing and frequency of applications
- ◆ All treatments on a property should be recorded
- ◆ GF-120 NF will allow 1–3 oz of bait spray per host or non-host plant. If the average is four hosts or non-hosts per property, then a property would receive an average of 12 oz of bait spray (3 oz × 4 hosts/non-hosts). If there are fewer than four hosts on a property, non-hosts should be used so at least four hosts or non-hosts are treated on each property
- ◆ Malathion's application rate is 0.18 lbs. active ingredient (a.i.) per acre

### Mixing instructions for GF-120 Naturalyte® fruit fly bait

GF-120 NF is a concentrate that must be diluted with water before use. The dilution rate is 1:1.5 (GF-120 NF: water). For example, to make 10 liters of spray solution, mix 4 liters of GF-120 NF with 6 liters of water.

- ◆ Add water (one half of the total volume of water) to the mixing tank and start the agitation system
- ◆ Add the full amount of GF-120 NF
- ◆ Use the remaining water (the second half of the total volume of water) to rinse the GF-120 containers
- ◆ Before disposal, empty GF-120 NF containers will need to be triple-rinsed; the rinsate from this process should be used in the mixing of the spray solution
- ◆ Dispose of rinsed GF-120 NF containers appropriately
- ◆ Agitate the spray solution for at least 5 minutes to ensure uniformity before dispensing it into individual sprayers

Example:

Total volume: 350 liters of spray solution (at a 1:1.5 dilution rate, this means 140 liters GF-120 NF:210 liters water)

Mixing instructions:

1. Add 105 liters of water to the mix-tank, agitate.
2. Add 140 liters of GF-120 NF to mix-tank (37 one-gallon

- containers).
3. Add 105 liters of empty container rinsate/water to mix tank.
  4. Agitate for at least 5 minutes before dispensing into secondary containers (*i.e.*, 2-gallon sprayers).

**IMPORTANT:** ONCE GF-120 NF IS DILUTED, IT MUST BE USED WITHIN 24 HOURS.

### Mixing instructions for Malathion/Nu-Lure®

*Malathion plus Nu-Lure® Insect Bait Mixture:* The only approved insecticide to mix with Nu-Lure® Insect Bait is malathion. There are numerous malathion brands with different amounts of a.i. Use a malathion product that is labeled for your crop. You must apply 0.18 pounds of a.i. per acre. The amount of product that is applied per acre will vary with the malathion formulation you purchase.

Following are some examples using the formula to calculate the amount of product you need to apply 0.18 lbs. a.i. malathion per acre:

- ◆ GOWAN® Malathion 8 Flowable—8 lbs a.i./gallon (128 oz)

$$\frac{8 \text{ lbs a.i./gallon}}{128 \text{ oz/gallon}} = \frac{\text{Need } 0.18 \text{ lbs/acre}}{X \text{ oz}}$$

$$X = 2.9 \text{ oz/acre}$$

- ◆ Bonide® Malathion—4.37 lbs a.i./gallon (128 oz)

$$\frac{4.37 \text{ lbs a.i./gallon}}{128 \text{ oz/gallon}} = \frac{\text{Need } 0.18 \text{ lbs/acre}}{X \text{ oz}}$$

$$X = 5.3 \text{ oz/acre}$$

**Table 6-1** Examples of Malathion and Nu-Lure® rates per 1-acre application

Brand	lbs a.i./gallon	Malathion rate/acre	Nu-Lure®	Amount of water per acre
Gowan® Malathion 8	8.00	2.9 oz	9.6 oz	10–40 gallons
Bonide® Malathion	4.37	5.3 oz	9.6 oz	10–40 gallons

It is critical to follow the label directions on the rates allowed per application, number of applications allowed per year and the application interval. If the interval is long (*i.e.*, every 30 days) or the number of applications allowed in a year too low (*i.e.*, no more than four), then the malathion must be rotated with the GF-120 applications.

- ◆ The water used for the solution should be buffered to pH 7.0 with an

available buffer material

- ◆ You **must** mix the malathion with Nu-Lure<sup>®</sup> Insect Bait. Follow the label and calculations above for proper use and rates. The Nu-Lure<sup>®</sup> rate is 9.6 fl oz/acre
- ◆ Mix the malathion plus the Nu-Lure<sup>®</sup> in 10 to 40 gallons of water and apply the entire amount throughout the acre, applying the foliar bait spray as a spot treatment
- ◆ If treating crops that are **not** listed on a malathion label, use the GF-120 NF

The effectiveness of Nu-Lure<sup>®</sup> may be decreased or slowed when applied over copper spray residues or when sprayed in tank mixes with copper.

*Calibration of Spray Equipment:* Note the following when calibrating spray equipment.

- ◆ Have all calibration equipment on hand: graduated cylinder, buckets, stopwatch and recording material
- ◆ Test the spray pattern and adjust for a large spray droplet size of 4–6 mm
- ◆ Place the spray nozzle into a graduated cylinder and note the time it takes to spray out the desired amount (*i.e.*, 1–3 oz). This is the amount of time it will take to apply 1–3 oz when conducting the treatments
- ◆ Calibration should be conducted every time the sprayer is filled, then calibrated periodically throughout the day

### Soil drenches

The use of soil drench under the drip line of host trees where invasive fruit fly species have been detected has historically been a key pest control component used in regulatory quarantine and eradication. In addition, soil drenches are also used as a regulatory treatment in the certification process to allow movement of known host nursery stock in containers outside of fruit fly quarantine areas as described in Title 7 of the CFR.

Lambda-cyhalothrin (Warrior II with Zeon Technology<sup>®</sup>, Syngenta Crop Protection, LLC, Greensboro, NC) is used as a soil drench to kill larvae and pupae in the soil and may be applied around mated female and larval detection sites or in fruit fly host production nurseries under quarantine. No other insecticides are currently available for regulatory soil treatments in fruit fly eradication programs. Lambda-cyhalothrin is a synthetic pyrethroid insecticide and acaricide.

Applications of lambda-cyhalothrin could occur within the drip line of fruit-bearing fruit fly host plants that are located within a 200 m radius from the

detection of mated female fruit fly, larvae or pupae or as a regulatory treatment on host containerized nursery stock and to soil around nursery stock to allow nursery stock to move out of the quarantine area.

A Special Local Needs (SLN) label needs to be obtained/registered for this use. Work with your State Department of Agriculture Pesticide Registration Office.

***Application Rate:*** Apply 0.4 lbs a.i./acre, which equates to a single maximum rate of 0.0092 lbs a.i./1,000 sq. ft. of soil surface. This equals 0.56 fl oz of product in 15.5 gallons of water/1,000 ft<sup>2</sup>.

***Mixing Instructions:*** Mix 0.73 fl oz of product in 20 gallons of water to form a solution/suspension. Fifteen and one-half (15.5) gallons will treat 1,000 ft<sup>2</sup> of surficial soil.

***Application within Drip Line of Fruit Bearing Host Plants:*** Applications will be made by or under the supervision of a licensed state or federal employee. Prior to application of the pesticide mixture, if necessary, remove all fruit from plant and pre-drench the areas to be treated with sufficient water to break the surface tension of soil and thereby allow adequate penetration by the insecticide. Based on risk assessment, drench the soil under the drip line of host plants located within a 200 m radius from a mated female or larval detection. Make treatments such that no surface liquid remains in order to avoid non-target exposure of humans, animals and non-target species. In areas where absorption is slow, applicators will remain on-site until the application has been absorbed into the soil.

***Applications on Regulated Host Nursery Stock:*** Applications are to be made by a licensed applicator under the supervision of the appropriate state or federal official. Chemigation is not allowed. Apply to nursery stock using equipment that generates a coarse, low pressure spray. Make applications using sufficient volume to soak the entire contents of the nursery stock container.

Do not drench to the point of runoff. Do not allow offsite movement of the treatment solution from treated area into sewers, drains, gutters or to any area where drainage to sewers, storm drains, water bodies or aquatic habitats can occur.

## Treatment Forms

Proper documentation of activities in ground treatment is extremely important and it is crucial that forms be completed promptly and accurately. Forms for ground

based treatment operations include the following:

- ◆ Ground Control Treatment Log: a record of the start and finish of each treatment cycle by location and date
- ◆ Control Branch ICS 214 (Unit Log): this log should record personnel number and type, routine activities and unusual activities or events, *etc.*
- ◆ Pre-Treatment Notice to Property Owner: this notice is left at each property 24 hours prior to treatment
- ◆ Post-Treatment Notice to Property Owner: this notice is left at a property where a treatment has occurred, but the resident/owner could not be reached. The Notice informs the resident/owner that the property was treated, the material used, the date and time applied and any precautions
- ◆ Residential Property Treatment Record: a list by date of individual properties treated or untreated, number of hosts and non-hosts, and other pertinent information about the property

## Larval Survey

Fruit fly host material on a property where a fly has been detected must be inspected for possible larval infestation. Small circular oviposition scars are occasionally visible, indicating a potential infestation. In the absence of visible scars, 100 or more pieces of host material (preferred hosts if available) should be cut open at random and examined for larvae. First and second instar larvae are small and may be feeding immediately under the surface of the skin; therefore fruit cutting should be left to experienced personnel. Fruit fly host material on properties adjacent to a detection should also be inspected for larval infestation.

If two or more flies are detected in close proximity, fruit cutting may be extended to all properties in a 200 m radius, concentrating on preferred hosts if available. Fruit can be inspected on the property or double-bagged and taken to another inspection site within the quarantine area. Do not move fruit fly host material out of the quarantine area.

## Fruit Removal

If there is evidence of a breeding population (larval or gravid/mated female), all fruit fly host material will be removed from all hosts within 200 m of a known infestation, safeguarded by double-bagging, and taken to a project-approved incinerator or landfill site for burial under at least one foot of fill. These activities must be completed on a daily basis.

Fruit removal is the physical removal of host fruit from plants or ground where fruit may have fallen, occurs at the detection sites and may extend outward to 200 m, depending on the severity of the infestation.

Personnel should be well trained, in good physical condition, safety conscious and willing to do the work. For large fruit removal activities, project-approved local contractors may be contracted to do this work.

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## Alternative Control Techniques

This section outlines alternate control treatments. These techniques are not applicable for quarantine purposes.

The economic objective of the control measures presented is to keep the maximum larval infestation of fresh market cherries to less than or equal to 2 percent of the marketed crop, and of canning cherries to less than or equal to 6 percent (Daniel and Baker, 2013). Sweet cherries with greater levels of larval infestation are sold to distillers at a greatly reduced price (Daniel and Baker, 2013).

Yellow sticky traps are used to mass trap as well as monitor the timing and density of moth emergence to guide timing of insecticide application (Daniel and Grunder, 2012). However, sticky trap results cannot be used to monitor for economic threshold because other variables in levels of larval infestation of fruit include the weather conditions during oviposition and the crop load—relative numbers of mated females (Daniel, 2014).

### Mass Trapping

Mass trapping with yellow sticky traps is used in organic cherry orchards as an alternative to chemical sprays (Daniel and Grunder, 2012). A field-tested prototype of an improved trap, with advantages over the widely used Rebell® amarillo cross-shaped sticky trap, was described by Daniel (2014).

Adults are visibly distinct, as described in [Chapter 4](#) and illustrated in [Figs. 4-1](#) and [4-2](#), and are trapped with yellow sticky traps placed in cherry trees or near honeysuckle (Daniel *et al.*, 2014). A sticky trap of three-dimensional design (visible from all directions) with a primary reflectance peak at 500–550 nm and a secondary reflectance peak at 300–400 nm was found to capture the most flies and to be the most practical trap among tested designs (Daniel *et al.*, 2014).

### Sanitation

For varieties that allow it (*i.e.*, early-maturing), cherry harvest should occur before mature pre-pupal larvae exit the host fruit to pupate in the soil.

Unharvested infested cherries are a source of larvae and pupae for the next generation, and thus should be removed (Daniel and Grunder, 2012). To facilitate

complete and early harvest, trees should be appropriately pruned and tree height limited to 10-m (Daniel, 2014).

## Cultural Controls

Fly emergence can be delayed by leaving grass growing uncut beneath tree canopies until shortly before harvest. The longer grass maintains the soil in a cooler state and thus can delay completion of fly development (Daniel and Grunder, 2012).

The emergence of adults from the soil can be reduced by covering the soil beneath tree canopies with white, fine-meshed (0.8 mm) netting. In two orchards over two years, soil netting reduced adult trap captures by 77 percent relative to un-netted controls; larval infestation of cherries was reduced 91 percent compared to controls (Daniel and Baker, 2013).

Netting (1.3 mm) developing cherries in orchards of dwarf trees protected by hail net or from rain by plastic covers is reported to be a cost effective means of excluding reproductive adults from host fruit (Daniel, 2014).

For new plantings, choose varieties that accommodate mechanical harvesting, which is more rapid than manual harvest (Daniel, 2014).

## Behavioral Control

The efficacy of the sterile insect technique (the release of sterile males in numbers that result in an economically significant reduction in the number of fertilized eggs oviposited) has been demonstrated; however, the narrow host range of this species requires a mass rearing technique based on an alternative host or artificial host that has yet to be developed (Daniel and Grunder, 2012).

## Biological Control

Foliar application of *Beauveria bassiana* (entomopathogenic fungus, formulated as "Naturalis®-L" bioinsecticide) is effective in organic cherry orchards (Daniel, 2014).

The efficacy of prospective soil treatments based on entomopathogenic nematodes and fungi versus pupae has been demonstrated in laboratory experiments (Daniel and Baker, 2013). However, efficacy could not be proven under field conditions; among unpublished results, nematodes were not effective, and fungi were only effective in years with heavy rainfall and persistent very wet soil conditions (Daniel, 2017).

*Rhagoletis cerasi* populations in Europe have been found to be infected with



distinct strains of *Wolbachia*, intracellular bacteria suspected of being agents of cytoplasmic incompatibility between infected populations. When males infected with one strain mated with uninfected females or with females infected with a different *Wolbachia* strain, the resulting embryos died; when males and females infected with the same *Wolbachia* strain mated, the resulting embryos developed (Riegler and Stauffer, 2002). Thus, through the mechanism of cytoplasmic incompatibility, infection with distinct strains of *Wolbachia* was found to have resulted in geographically distinct *R. cerasi* populations in Europe (Arthofer *et al.*, 2009a). The prospect of applying cytoplasmic incompatibility, based on *Wolbachia* infection, to prevent an introduced population from becoming established has been proposed, but has not developed and implemented (Riegler and Stauffer, 2002). The limiting factor for this approach is the mass rearing of *R. cerasi* (Daniel, 2017). The challenges to mass rearing of *R. cerasi* include the following:

1. *Rhagoletis cerasi* only oviposits in round objects, which are more expensive to produce than simpler oviposition substrates.
2. *Rhagoletis cerasi* marks the oviposition site after oviposition, which results in only one egg/oviposition substrate and makes frequent replacement of oviposition substrate necessary and very labor intensive.
3. Usually, under field conditions, only one larva per cherry is found. If two larvae meet within a fruit, they attack each other, and the older larva typically kills the younger one. Therefore, during laboratory rearing, larvae need to be kept individually, which can be costly in labor and materials.
4. There is only one generation per year with a long obligatory winter diapause, making the rearing of a single generation very slow with high facilities costs.

# Research Needs

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New technology, research or assessment is needed to:

- ◆ Determine the efficacy of sentinel cages for monitoring adult emergence
- ◆ With the objective of increasing the ratio of actionable information to surveillance costs, identify existing or prospective networks by which soil temperature can be monitored in real time in order to identify when to begin monitoring host space for active adults
- ◆ Optimize mass rearing of *R. cerasi* to facilitate inundative *Wolbachia* infection–based cytoplasmic incompatibility, relative to sterile insect releases, in preventing an invasive population from becoming established
- ◆ Assess approved Tephritid chemical regimes against *R. cerasi*

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# Chronology of Action

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Once a fly has been detected, the chronology of action is as follows:

- ◆ 24 hours: Trap density increased to protocol levels within core area around each fly find
- ◆ 48 hours: First inspection of traps
- ◆ 72 hours: Trap density increased to protocol levels in 81-mi<sup>2</sup> area around each fly find
- ◆ First week: Daily inspection of project traps in core area
- ◆ Second week: Weekly inspection of project traps

Ground treatments conducted within a minimum of 200 m around the wild fly find begin as follows:

- ◆ 24–36 hours: Notification and larval survey begins
- ◆ 24–48 hours after notification: Pesticide treatment (bait spray) begins
- ◆ First week: Completion of first pesticide treatment

Handle any new treatment areas established due to additional fly finds within the same time frame as the first area.

# *Rhagoletis cerasi* Action Plan Summary

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## ***Rhagoletis cerasi* Detected:**

1. 81-square mile area delimiting grid/survey initiated—less than this if within an existing sterile PRP (approximately 9 mi<sup>2</sup> depending on the infestation level).
2. Fruit cutting conducted within 200 m of fly finds (larval survey) for three life cycles while hosts are available.
3. Ground applied bait sprays conducted within 200 m of fly finds for three life cycles (optional).
4. If triggers are not reached after three life cycles: no quarantine action or further survey/treatments.
5. If triggers are reached:
  - a. Initiate quarantine/regulatory action within 4.5 mile radius of fly finds.
  - b. Conduct larval survey around fly finds for three life cycles out to 200 m.
  - c. Based on pest risk, terrain, topography and available hosts, conduct ground applied bait sprays within 200 m of fly finds for three life cycles or aerial applications of pesticides within a 0.56 mi radius of fly finds.
  - d. After three negative life cycles of trapping, release area from quarantine and all corresponding regulations.

# Instructions for Fruit and Vegetable Growers inside the Fruit Fly Quarantine Area

## Thirty-Day Pre-Harvest Treatment Program for Fresh Fruit and Vegetables

### GF-120 NF or Malathion/Nu-Lure® Bait Treatments

1. If your farm is within the fruit fly quarantine area, but not in the 0.5 mile arc core area, and your crop is on the host list, you must sign a compliance agreement with the Fruit Fly Eradication Program and follow a specific 30-day pre-harvest bait-spray treatment before harvesting your produce. Please call the Program Regulatory Office to sign a compliance agreement.
2. Keep detailed records of your bait-sprays (*i.e.*, GF-120 NF or malathion plus Nu-Lure®) purchases, use rates, use pattern and dates of application.
3. Bait-spray applications must begin 30 days prior to harvest, with applications made every 6–10 days and continued throughout the harvest season.

Note: If a quarantine fruit fly is trapped on or near your site (within a 0.5-mile arc) anytime during the 30-day pre-harvest period, you will be disqualified from the pre-harvest treatment option. Post-harvest treatments, if available, will apply in such cases. Examples of post-harvest treatments will include methyl bromide fumigations and cold treatments, among others.

4. There are only two approved bait-insecticides for fruit fly eradication programs: **GF-120 Naturalyte®** (Spinosad, Dow AgroSciences LLC, Indianapolis, IN), an organically certified mixture of spinosad and fruit fly bait, and **malathion<sup>3</sup>** (various manufacturers) **plus Nu-Lure® Insect Bait** (Miller Chemical and Fertilizer Corp., Hanover, PA).

<sup>3</sup> Not all crops or this defined application regime are listed on malathion labels. If your crop is not listed on the malathion label, it is illegal to use on your crop. Therefore, the GF-120 NF might be the only treatment option unless a Special Local Needs label can be obtained under the authority of §24(c) of FIFRA for the use of a federally registered malathion product to meet special local needs of the program.

## Instructions for Applying the Bait-Sprays

### Malathion/Nu-Lure® and GF-120 NF bait-sprays

This must be applied at a low volume application either as a hand-wand type spot-spray or with ultra-low volume application equipment.

Spot-spray equipment for the bait-spray applications include a 2 to 4-gallon backpack sprayer and a 1 to 5-gallon (hand-wand type pump-up) sprayer. Larger capacity spray equipment (ultra-low volume) that can be adjusted or retooled to apply large droplet sizes (4–6 mm) may be used; however, contact the Program Regulatory office to be sure your application method meets the application requirements for the harvest certification program.

### GF-120 NF Naturalyte® fruit fly bait (EPA Reg. No. 62719-498)

This is used as a very low volume hand-wand–type spot-spray application. This is NOT a high volume air-blast or high volume hand-gun type application. You must follow the label directions on the concentrations and mixing.

The proper GF-120 NF rate is 20 oz of GF-120 NF mixed with 30 oz of water (this is a dilution rate of 1:1.5) per acre. The reasons for this rate and dilution are as follows:

- a. This is the most effective concentration (*i.e.*, attracts and kills fruit flies better).
- b. The efficacy of GF-120 NF lasts longer at this rate.
- c. At this dilution rate (1:1.5), the material is least affected by rain.

#### *Application Directions:*

1. Use a large spray droplet size (4–6 mm). Set your nozzle tip or use nozzle tips that provide large droplets.
2. Calibrate your spray equipment to deliver sufficient amounts with every burst of spray so that you can distribute 50 oz of material (20 oz GF-120 + 30 oz water) throughout an acre of plants.
3. Direct the bait spray to one or two spots (areas) on the inner canopy of the plant, spraying the underside of leaves on the inside of the canopy. This reduces the direct sun exposure and the potential for washing off of the material by rainfall. The idea is to create an area where a fruit fly would feed on the bait/insecticide and perish. This is not a contact insecticide.
4. The pattern of application throughout the treated acre may depend upon plant type, size and spacing. The perimeter and inside of the planting should be sprayed. The main goal is to be sure to equally distribute the 50 oz of bait spray (20 oz GF-120 + 30 oz water) throughout the entire one

acre.

- ◆ For example: In tree crops, spot treat every third or fourth tree around the perimeter, then inside the acre, spray every fourth to fifth tree in every fourth row. To be most effective, the pattern should change slightly with each successive application
- ◆ For example: In vegetable crops, spot treat the perimeter and then spot treat at a reasonable distance down every fifth or sixth row. To be most effective, the pattern should change slightly with each successive application

The REI (restricted entry interval) and pre-harvest interval for GF-120 NF is four hours.

### Malathion plus Nu-Lure® Insect Bait mixture

The only approved insecticide to mix with Nu-Lure® Insect Bait is malathion. There are numerous malathion brands with different amounts of active ingredients (a.i.). Use a malathion product that is labeled for your crop. However, you must apply 0.18 lbs of a.i. per acre. The amount of product that is applied per acre will vary with the malathion formulation you purchase.

Following are some examples using the formula to calculate the amount of product you need to apply 0.18 lbs a.i. malathion per acre:

- ◆ GOWAN® Malathion 8 Flowable—8 lbs a.i./gallon (128 oz)

$$\frac{8 \text{ lbs a.i./gallon}}{128 \text{ oz/gallon}} = \frac{\text{Need } 0.18 \text{ lbs/acre}}{X \text{ oz}}$$

$$X = 2.9 \text{ oz/acre}$$

- ◆ Bonide® Malathion—4.37 lbs a.i./gallon (128 oz)

$$\frac{4.37 \text{ lbs a.i./gallon}}{128 \text{ oz/gallon}} = \frac{\text{Need } 0.18 \text{ lbs/acre}}{X \text{ oz}}$$

$$X = 5.3 \text{ oz/acre}$$

**Table C-1** Example of Malathion and Nu-Lure® rates per 1-acre application

Brand	lbs a.i./gallon	Malathion rate/acre	Nu-Lure®	Amount of water per acre
Gowan Malathion 8	8.00	2.9 oz	9.6 oz	10–40 gallons
Bonide Malathion	4.37	5.3 oz	9.6 oz	10–40 gallons

It is critical to follow the label directions on the rates allowed per application, number of applications allowed per year and the application interval. If the interval is long (*i.e.*, every 30 days) or the number of applications allowed in a

year too low (*i.e.*, no more than four), then the Malathion must be rotated with the GF-120 applications.

This is also a low volume application and may be applied in the same way as the GF-120 NF spot treatment type application or with spray equipment that is capable of applying 10–40 gallons of material (Malathion/Nu-Lure<sup>®</sup> plus water) per acre with the proper droplet size (4–6 mm). Contact the Program Regulatory office to be sure it meets the application requirements for the harvest certification program.

Malathion products must be applied at the rate of 0.18 lbs per acre as a foliar bait-spray treatment at a 6 to 10-day interval for the 30-day pre-harvest treatment, and continued at intervals of 6 to 10 days throughout the harvest season.

- ◆ The water used for the solution should be buffered to pH 7.0 with an available buffer material
- ◆ You **must** mix the Malathion with Nu-Lure<sup>®</sup> Insect Bait. Follow the label and calculations above for proper use and rates. The Nu-Lure<sup>®</sup> rate is 9.6 fl oz/acre
- ◆ Mix the Malathion plus the Nu-Lure<sup>®</sup> in 10 to 40 gallons of water. Apply the bait spray as a spot spray equally throughout the acre, treating the perimeter and inside of the planting in a similar pattern to the GF-120 NG application described above
- ◆ Growers with crops **not** listed on a Malathion label should use the GF-120 NF

The effectiveness of Nu-Lure<sup>®</sup> may be decreased or slowed when applied over copper spray residues or when sprayed in tank mixes with copper.

In addition to the bait-insecticide application procedures, all producers must follow the compliance agreement for moving produce from their farm in and out of the quarantine area.



# Current Grower Practices in Place for Other Cherry Pests

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Current management practices in cherry growing regions in the U.S. include the following:

- ◆ Dimethoate and acetamiprid are currently registered for use in cherry to control fruit flies in the United States (Castagnoli *et al.*, 2016; Wiman *et al.*, 2016; WSU, 2016)
- ◆ Additional insecticides that are currently registered for control of fruit fly in cherry in the United States include the following:
  - Carbamates
  - Diamides
  - Organophosphates – malathion (see local recommendations; contact local extension for approved labels)
  - Neonicotinoids
  - Pyrethroids
  - Spinosyns

(Castagnoli *et al.*, 2016; Wiman *et al.*, 2016; WSU, 2016)



*R. cerasi*

# Authors and Reviewers

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## Authors

Jennifer C. Cook, Ph.D., NCSU–CIPM

Jaap van Kretschmar, Ph.D., NCSU–CIPM

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## Editor

Katie Hurst Deutsch, NCSU–CIPM

---

## Reviewers

Kenneth Bloem, Ph.D., USDA–APHIS–PPQ–S&T

Claudia Daniel, Ph.D., Research Institute of Organic Agriculture FiBL

Lisa Jackson, USDA–APHIS–PPQ–S&T

Heather Moylett, USDA–APHIS–PPQ–S&T

John C. Stewart, USDA–APHIS–PPQ–PHP

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## Cover Image

*Rhagoletis cerasi* on cherry and on a leaf (image credit Stephanie A. Hill, Mississauga, Ontario)

Cherry damage from *R. cerasi* pupae (image credit Claudia Daniel, Research Institute of Organic Agriculture FiBL)